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Energy Procedia 30 (2012) 1311 – 1321

Energy Procedia

SHC 2012

Interaction of regulation and innovation: Solar air heating collectors

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Abstract

Solar Air Heating Collectors have still a very small share of 0.8% of the nominal installed capacity in the solar heating and cooling market (151.7 GW_{th}) [1]. Although constituting a niche market, the potential of those kind of collectors to provide heat for industrial processes, processing food, room heating, air preheating, drying processes or air conditioning could be significant. However, the technical potentials of the various technological solutions are not easy to compare. Such a comparison would be important for different interest groups: end consumers (cost/kWh), technicians (efficiency, long time durability), planers and designers (amortization time) and politicians (CO_2 savings, national energy autonomy). In order to certify or rate technological variants it is necessary to have a standardized procedure for characterization based on scientific results. Important achievements were made in this respect within the last three years in Germany. The paper presents the latest results in characterizing methodology for the different kinds of Solar Air Heating Collectors. It also discusses the implicit consequences which the interaction of testing methodology and regulative policies has on the innovation, diffusion and technical development.

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Keywords: Solar air heating collector, certifiation, standardisation, characterisation, solar collector

1. Introduction

The market share of Solar Air Heating Collectors (in the following: SAHC) is growing (growth rates of 20%-50% [6]) especially in Canada and Germany. In Canada the un-glazed collectors do prevail, in Germany almost only glazed collectors are installed [1]. Nevertheless SAHC are still in a niche within the global solar heating and cooling market [1, 5]. Becoming more relevant in some markets the technology should be covered by the existing as well as by up-coming regulations and subsidy schemes to level out the political support for this rather new and more established technologies. To do so in a fair and sound way, multiple boundary conditions for testing, certification, inter-comparison and rating have to be defined. This paper focusses on the interaction of regulations (Norms, Laws, Certification Scheme Rules

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doi:10.1016/j.egypro.2012.11.144

…) and technical consequences induced. To make this kind of interaction more visible, the main interacting forces are described and analyzed in the first three chapters. This is exemplified for the German market in this paper. There the number of installed collector area is the highest in Europe [1], and regulations and subsidies have been in force for several years. Also some of the most experienced producers of SAHC are located in Germany. The basic risk factors described and also the solutions suggested for Germany are nevertheless transferable to other similarly structured markets.

Chapter 2 is starting with information on the three pillars of regulations and policies, which are most important for the example of SAHC and the German market development. It also shows the regulatory gap for innovative products from this sector.

Chapter 44.1 is giving some technical definition and explanations important to understand the innovation described later in the paper. These technical definitions are also important to detect the influence regulations have on the technical development.

Chapter 5 explores a recent example of innovation in the field of SAHC. It depicts the influence of external market forces on the product design.

In chapter 6 the lessons learned are summarized. Moreover perspectives and the on-going adjustments of the national innovation system are mentioned.

2. The example of the German market incentive programs

As in almost all countries around the world the supply of conventional fuels for heating like gas and oil is heavily subsidized. This is done by neither including infrastructural costs nor any consecutive externalities due to burning it. The end consumer has only to pay for the microeconomic fuel costs. For a compensation of these effects it is necessary to subsidy renewable energies to balance the distorted market forces.

A second argument for even higher subsidies is that the products deliver a benefit to society, which cannot be transferred into monetary benefit by the companies bringing these technologies into the market. In such a case it is wise to internalize these benefits in the prize of the beneficial product [12] by subsidizing it. So that the overall benefit for national economy and society is kind of paid for and thereby transferred again into the systematic of pricing and free-market economy. The alternative to this strategy of course would be to internalize all externalities on conventional energies, but still this would not make up for the later effect.

The German heating and cooling market is regulated by different kind of governmental regulations. For the field of Solar Thermal the most important tools for the market development recently are;

- The Renewable Heating Act (EEWärmeG = Erneuerbare Energien Wärme Gesetzt)
- The Market Incentive Program (MAP = Markt Anreiz Program)
- The low interest rate program of the German Promotional Banking Group (KfW).

These three main pillars of the promotional system for heating technologies in Germany have because of their requirements and their structure an effect on products developed. To some extend this influences the innovation rate as well [2]. Because after incremental innovation for example testing according to the certification scheme rules is necessary. This leads to some extra costs and testing periods. Some manufacturers therefore do accumulate new developments and provide revised or new versions of their products only in a slower rate to the market. One can assume that somehow by structuring the processes the quality is improved on the other hand.

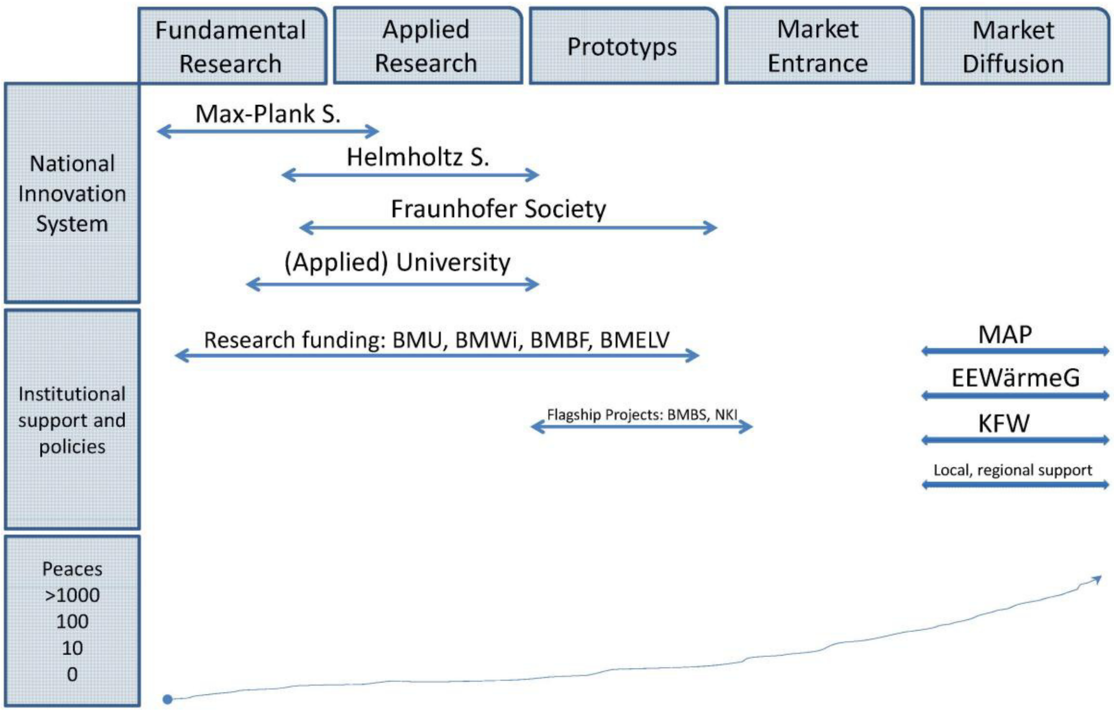

Fig. 1. Gives an overview on different stakeholders who interact as the innovation system for new products. As well the regulatory pull can be seen which is provided by the institutional Policies. The trend line on the lower part of the graphic illustrates that there is on the one hand a gap in the policy system to support market entrance at an early stage. On the other hand one can see what a difficult situation an innovative product is in, when it has no access to the three main pillars of market diffusion support. [Translated and adopted on bases of 17]

In the case of SAHC the situation is even more complicated. In principle SAHC are to be subsumed with the wording "solar collector". Hence they have to be Solar Keymark labeled as other collectors to be recognized for the EEWärmeG [9, S.10] or the MAP. To see the consequences in details resulting from the interacting structure, first the basic structure is explained. Further on the exclusive regulation is explained as it was introduced to act like a bridge regulation for the special case of SAHC. Chapter 2.1 will give details on that.

As any other solar collector the SAHC have to provide the minimum collector gain, presented on basis of the BAFA Simulation (details in chapter 2.1) [11, S.7].

2.1. The Market Incentive Program (MAP)

The MAP is a program for different kind of heating systems (e.g. biomass, heat pumps, solar). It is financed by federal budget money through the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Office of Economics and Export Control (BAFA) administratively runs it. It covers beneath other renewable heating technologies, solar heating and domestic hot water preparation as well as industrial solar process heat. The subsidies are paid directly to the end consumer in single step application approach. Subsidies are paid, if the following requirements are fulfilled:

- The first requirement is that the product is Solar Keymark labeled. The Solar Keymark Label is the quality label supported from the ESTIF (European Solar Thermal Industry Federation) and widely used in Europe. The labeling process again is based on Scheme Rules, which state that the label can be attained for products, which passed a complete testing according to the relevant EU Standard. For solar collectors this is at present EN 12975-1, 2:2006-A1:2010. SAHC are on the other hand excluded from the scope of EN 12975-1, 2:2006-A1:2010 [13]. So it is not possible to fulfill this requirement.
- The second requirement to get on the BAFA´s list of collectors possible to be subsidized [5] is, that the product achieves 525 kWh /m² collector minimum energy gain. This value is calculated using a trnsys simulation for a specific system configuration in Würzburg (German City with yearly insolation of ~ 1212 kWh/m²). It is actually quite old-fashioned providing a load profile for domestic hot water only, with a solar fraction of 40% and a 200l heat storage tank volume. It is also not applicable for Solar Air Heater. So the second requirement of the MAP is not possible to be fulfilled for a SAHC.
- The third requirement for MAP is a very simple one on at first glance. The collector has to be glazed [11, S.8]. Chapter 4.1 will discuss this in detail.
- The forth requirement for MAP´s subsidies is dealing with the use of the system. So the subsidy is only paid if the intention of the system is to provide both hot water and heating, industrial process heat or if the collector gross area of the systems is bigger than 20 m² and build in existing building stock [11].

2.2. The Renewable Heating Act (EEWärmeG)

The second pillar of subsidy in Germany for renewable heating and cooling technologies is the EEWärmeG. This law is requiring a minimum share of renewables or energy efficiency means in the building sector and in a second step in the existing building stock [9]. Different possibilities to reach the required 15% share of renewables are possible. As an alternative also the energy efficiency of the building can be reduced below the EnEV 2009 standard to account for this share. Another solution is to install a solar thermal system. If one chooses this possibility the minimum requirement is to install 4 m² collector gross area per every 100 m² living space. So a system configuration is generated which is at least providing a high solar fraction on domestic hot water (DHW) demand. To contribute a significant heating support more area has to be installed. This “more” is voluntary so you get subsidy on the square meters by the MAP again. The EEWärmeG is requiring the Solar Keymark Label as prove of quality. Only products, which are labeled, are accepted for fulfillment of the EEWärmeG [9]. From the chapter 2.1 it is already clear that this is impossible for SAHC.

2.3. The low interest rates grant (KfW)

The third pillar of subsidizing renewable heating technologies in Germany at the moment is a special grant at very low interest rates from KfW. It can be applied if energy efficiency improvements are undertaken or in case of a new building if it is build under fulfillment of some requirements. The overall concept of the building has to be proven to be high efficient and/or low energy consuming. This is demonstrated by calculation. Calculation in regards to the energy contribution of solar thermal systems are accepted if performed according to DIN V 4701-10:2003-08 or DIN V 18599-5: 2007-02 [14, S.19, S.

9], in case of a passive house according to DIN EN 832 [14][a]. The explicit benefits and strategies coming with SAHC are not taken into account.

3. The Solar Keymark (SKM) certification

Following the explanations of chapter 2 it is important now to understand how a Solar Keymark label can be achieved. As well it is interesting to understand what the Solar Keymark label stands for. This is explained in the following. The Solar Keymark Scheme rules ask for three main requirements to grant the quality label.

- A report from an accredited test laboratory providing all technical information and results of a test performed on the product according to a published EU standard applying as well all rules of Solar Keymark (e.g. product for testing sampled by a neutral third party)
- A report on an initial factory inspection without major problems, which could be a risk for a continuous quality of the production
- A complete filled-out data sheet for publication of the main test results from the test prepared by a neutral accredited and certified test laboratory

The Solar Keymark (SKM) label is representing towards end consumer and policy makers that the product passed all necessary quality checks for solar collectors. Often it is misinterpreted to show an especially high performing product. This is not the case. But the test according to the standard and the publication of the results make sure, that all the products are described and characterized in a comparable way and so for the free-market transparent information is available to base their buying decision on.

3.1. The bridge regulation in the MAP

As described already there is no European standard available for SAHC right now. So the first requirement of SKM can not be fulfilled. The second requirement can be fulfilled recently. The third requirement can not be fulfilled because a data sheet for SAHC is not available from the Solar Keymark Scheme Rules or the Solar Keymark Network (group of international experts and stakeholders of the SKM).

In this situation some representatives of the stakeholders involved (representatives of test laboratory, BAFA, BMU, Certifier and Manufacturer) have designed a *bridge regulation* to overcome this hurdle for SAHC and to provide a levelled market access also for this innovative niche product. SAHC collectors may be subsidies by the regulation of the MAP, if the producer provides:

- A test report showing all necessary test results and technical data in a comparable way, which is as close as possible to the procedure and standards applied for solar water heating collectors (SWHC)
- A minimum collector gain by calculation (as soon as available)
- Of course the criteria already mentioned in chapter 3 (e.g. to be glazed) have to be fulfilled

[a]EnEV 2009 calculation is applicable for flat plate collectors only.

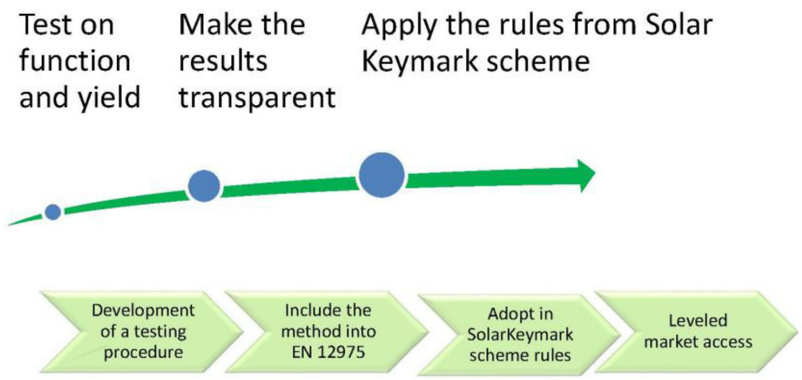

Fig. 2. Sketch on the transition regulation (bowed arrow) to bridge the time until the official regulations (process arrows) have been adopted. In both cases the leveled market access for the innovative technological variant is the focus and achieved

The next chapter therefore explains what technical information, what tests and what information on the product have been defined to meet the requirement of being described similar to SWHC. To identify these requirements there was a project initiated in Germany by Fraunhofer ISE in 2009 called LuKo-E, which is funded partly by the BMU and involved six manufacturers of relevant products. The project will go on until March 2013. Within this project several products could be tested and experiences were made. Also international literature and standards were studied to validate, resume or revise ideas already published elsewhere on this topic (e.g. CSA F378.2). Fraunhofer ISE is also active in the international standardization organization ISO and its relevant technical committee TC 180. As there was a mandate from ISO towards TC 180 to revise the ISO 9806 on solar collectors in 2009, there was the decision taken, to include SAHC during this revision. Fraunhofer ISE prepared therefore the relevant new chapters and adoption of existing chapters in ISO 9806 to enlarge the scope of the standard by SAHC. So the technical explanations given in the following chapter are represented in the method implanted in ISO DIS 9806. Chapter 6 will give some more information on the outlook of this process.

4. Parameterizing the performance of solar air heating collectors

To determinate the performance figures for SAHC, different preliminary boundary conditions have to be clarified. Depending on what kind of technical variation one is dealing with, different approaches in the set up and in the testing sequences have to be chosen. The next chapter therefore defines the different generic variants, which have to be differentiated technically and at testing.

4.1. Generic differentiation of solar air heating collector technics

One basic technical specification is if the product is glazed and un-glazed (some literature also uses the expression, covered or un-coveredb). The definition of ISO 9488:1999 for an un-glazed collector is "solar collector without a cover over the absorber" [15]. The physical phenomenon, which is the reasons to differentiate these technical variants are the very different loss mechanisms of these solar collector types. The losses are the combination of the free convection between a potential transparent cover plate and the forced convection influenced mainly by the wind and ambient temperature. Another effect is that a cover reduces the radiation losses of the hot absorber plate towards the cold sky temperature. In the following two definitions are discussed to differentiate the two types.

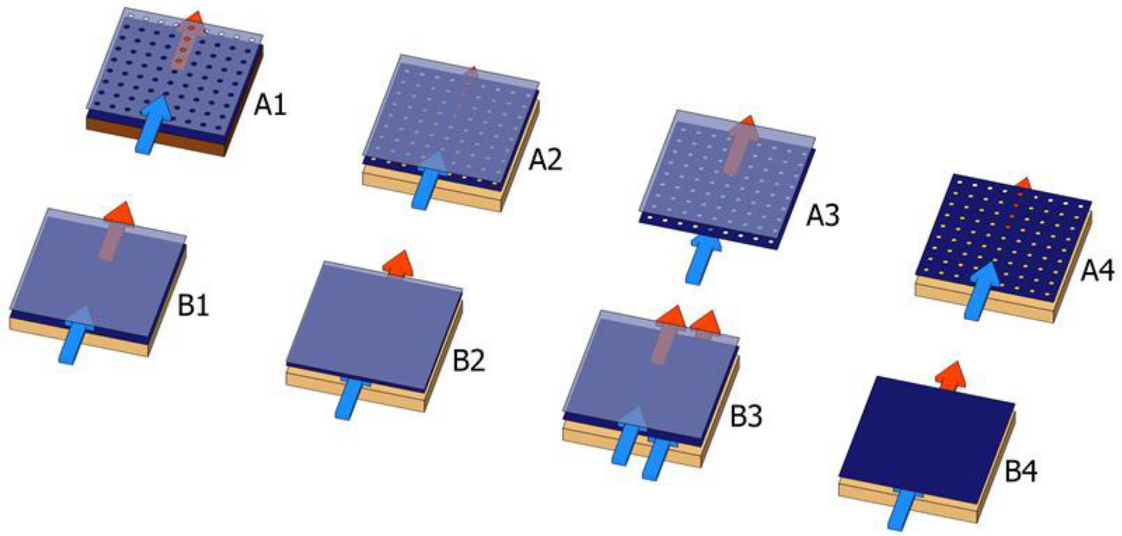

Fig. 3. Shows the different technical variants of SAHC [8]. Variants A1 to A3 and B1 to B3 are treated as glazed collectors. The light blue plane represents the transparent cover, the dark blue plane the absorber and the beige block represents isolation. Variants A4 and B4 are described as un-glazed. Variants B1 to B4 are part of a closed loop of an air heating system, thereby potentially reaching higher outlet temperatures. Where else the variants A1 and A4 are heating ambient air in a single path through. Variant A2 and A3 could be used in both flow patterns. The blue arrow symbolizes the cold inlet air flux and the red is representing the hot air flux. From this arrows one can see, that some variants are from the point of view of the absorber, under flown (B2, B4), over flown (B1) or passed through (A1 to A4).

Glazed collectors are of such kind, that the external convective losses are reduced by separating the forced convection losses from the absorbing (hottest layer in the collector) part.

This leads to higher temperatures at the absorber and therefore potentially to higher temperatures in the heat transfer fluid.

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[b] The author prefers the wording covered instead of glazed, as the cover does not have to be made of glass, in this paper nevertheless the official ISO 9488 wording is used.

Un-glazed collectors are of such kind, that the forced convection losses are directly cooling the absorbing part.

Of course convection is forced to transport heat via the air from the absorber into the heating system as well. But this heat transfer medium flow is per definition not a loss. Speaking of forced convection losses therefore only describes the wind speed induced losses by convection. Even these definitions are not without problems. In variant B3 for example the absorber is separated from the convection losses, but by passing the heat transfer fluid between absorbing part and the cover which is exposed to the wind, the temperature of the heat transfer fluid is again influenced by the external forced convection.

A second, more hands on definition of un-glazed and glazed in the sense of testing could be.

Glazed collector means, that the influence of the wind speed on the thermal performance of the collector is negligible.

Un-glazed means the influence of wind speed on the collector performance has to be described by an extra parameter.

From the point of view of the MAP the definition of excluding un-glazed collectors from subsidy surly makes no sense. The idea behind is of course to subsidies only products, which contribute significantly to energy efficiency or savings. But the assumption that this is a privilege of glazed collectors is not accurate. In the situation of a not so well defined wording, it becomes clear first glance that this requirement in the MAP is not adequate, but also from a technical points of view it is not accurate[c]. This issue is as well of importance for other innovative technics, like concentrating solar collectors (CSC) and PVT collectors.

4.2. Empirical determination of instant efficiency

This chapter summarizes the technical solutions on how to describe the performance of different air heating technologies in a comparable way, for details on this topic please also see [8]. Following dependencies have to be described:

- Mass flow; the heat transfer is strongly coupled with the flow condition (laminar, turbulent) and the temperature level
- Pressure drop; by knowing the pressure drop across the collector, the parasitic energy for the fan can be calculated.
- Reference temperature; one can choose between inlet, mean fluid and outlet temperature to relate a graphical compilation to it. There are advantages and disadvantages for all of them, in the prEN ISO 9806 therefore all values are provided, to keep it as transparent as possible.
- Wind dependency; the wind might have a quite strong influence on the performance of the collector; this shall be taken into account accordingly.
- For open to ambient SAHC only efficiency points are reasonable, because they heat always from the level of ambient temperature. These points will vary nevertheless with the mass flow.

From these multiple dependencies [7, 8] one can see that describing those kinds of products with only one factor or even only one efficiency curve is not suitable for further investigations (e.g. simulation of yearly collector gains). Therefore it is recommended in the new standard prEN ISO 9806 to provide the

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[c] A concentrating collector for example can contribute significant amounts of energy savings when using an un-glazed absorber, there will be a publication on this topic from the author in a separate paper.

measurement values, and only a basic number of graphical compilations, so that every national requirement can be met by own re-arrangements. This also levels the marketing based idea to optimize products on single technical parameters.

4.3. Analytical or empirical determination of Incidence Angle Modifier (IAM)

For some SAHC types, IAM measurement is not possible at reasonable effort. To keep it technical-vise correct, but still the testing cost as low as possible, the suggestion is to use ray-tracing software or equivalent to determine this important value. Keeping the testing cost low is important. Innovations, which lead in the scheme rules of almost all certification programs to retesting of products, are otherwise coupled with such high costs, that the innovation rate will slow down [2].

4.4. Comparability and scalability of the results

To be able to compare different products on the market based on the results from the certification process, it is of course very important to have correct, trustworthy measurement equipment with high repeatability and accuracy [7]. For SAHC these have been developed and improved in the past years, so this purpose can be achieved. This aspect is the basis for certification. Only if industry and the end consumer can trust in the technical values provided by certification, certification can help to develop the market and pull diffusion.

5. Example for a recent innovation of SAHC

This chapter gives a short example of a technological development to illustrate how technology developed is fitted to the regulatory boundary conditions. It is difficult to prove if innovation would have had taken place if boundary conditions would have been different. On the other hand the described example is interpreted by the author to be fitted towards or at least strongly influenced by the regulatory boundary conditions or the regulatory pull [16] (which include the innovation system of the product). For several years un-covered absorber plates are sold on the market, especially in Canada [1]. As the market in Canada is no longer state-aided new markets like Europe are in the focus of manufacturers of such products. Germany is within Europe the biggest market. The subsidy system in Germany does not support un-glazed collectors though.

The innovation in this case is to cover an un-glazed collector in such a way, that the collector will be accepted as a glazed one, which opens up potentially the MAP-subsidies. On the other hand the product should not cost more than an un-glazed collector already available on the market, because the two products will compete on the very same market segment. So according to the definition of ISO 9488, the collector is a glazed one, if there is a cover over the absorber. In this very case the wall the cover is mounted on, is defined to be the absorber (Fig. 3, A1). The cover can be made out of variations of translucent polymers. In a configuration like a darkish blue perforated cover and a white wall, the absorption may take place with a higher proportion in the transparent cover than at the wall. In such a configuration the cover becomes more like an absorber and by this the collector becomes rather an un-covered one than a covered. What is to prove of course is, under which circumstances the minimum yearly energy gain can be achieved and how this can be simulated in accordance with the MAP. As soon as the simulation for such collectors is available also un-glazed collectors might be simulated. From the results of those simulations it will depend if a change in the MAP is also an alternative to think about.

6. Conclusions and outlook

The complex situation for the niche product of SAHC was solved very pragmatically for the market of Germany. The official process of integrating the innovative products has been started and is almost finalized. This process was only possible through the financial support from German government, as the producers of these products would by far not have been able to finance the standardization work necessary [2]. The following lessons were learned throughout this process and may be transferred to other technologies:

- As well on the regulatory side as well as on the technological side lots of experiences were gathered on how SAHC (or other innovative products not covered in the scope of a standard) can be handled.
- Methodologies were developed and empirical determined boundary conditions defined to make it possible to characterize different SAHC in a sound and consistent way.
- Test stands and measuring equipment was developed to guarantee a high accuracy and a scientific approach for characterization of SAHC.
- A draft standard covering all forms of SAHC has been developed and published for inquiry. It will be most likely available as an EN ISO 9806 from 2014 on.
- The Solar Keymark scheme rules will be adapted to provide the label for SAHC as well then.
- Based on these achievements, certification can now help to push the market and speed up diffusion of SAHC.
- A way of how to overcome the problem with the simulation of the minimum energy gain is in process and will be published in 2012.
- The lessons learned from the SAHC, that it is important to have a flexible bridge regulation in parallel to further developing the standard path of certification on all levels will be transferred to other technological variants in a similar situation (e.g. PVT collectors, CSC) and published soon elsewhere.
- A proposal to fill the gap of policy for products in such an early state was developed and published [17].

Acknowledgements

The work was partly funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety by means of the project “LuKo-E” (0325959A). The PhD thesis oft he author which covers the topic of the paper is counseled by Prof. G. Oesten, Prof. V. Wittwer (University of Freiburg, Germany), Prof. M. Rommel (Hochschule für Technik Rapperswil, Switzerland) and Prof. E. Meidinger (Buffalo University of New York, USA).

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